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BIO-FUELS: GREEN ENERGY FOR DEVELOPMENT

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ABSTRACT

In the context of fast declining non-renewable energy reserves and deteriorating global environment, sustainable development is much dependent on wider adoption of bio-fuels. Different options of bio-fuels include bio-ethanol, bio-diesel and gasification of biomass to generate electricity. Ethanol extracted from molasses, a residue of sugarcane, saves country's foreign exchange, benefits environment as carbon di-oxide emission is less. The plant species commonly used for ethanol production are sugarcane, maize, sweet sorghum and sugarbeet. Bio-diesel consists of the fatty acid esters of simple alcohol and can potentially replace a portion of diesel fuel used in transportation. Methyl and ethyl esters of rape, linseed and sunflower oils were prepared through transesterification using KOH and/or sodium alkoxides as catalysts. The seed oil of *Jatropha curcas*, a drought resistant tropical tree, has been identified as a potential source for the production of bio-diesel. On ecological and socio-economical grounds, use of biomass as solid fuels for the generation of electricity may be preferred to conversion of biomass to liquid fuels. The biomass crops suitable for the generation of electricity are silage maize, hemp, poplar, willow and eucalyptus. To gain a maximum benefit of energy crop, there has been pursuance of research and development on identifying these crops, their adoption into the farming systems with perfection of agronomic practices, monitoring ecological consequences and socio-economic feasibility.

KEY WORDS: bio-fuel, bio-ethanol, bio-diesel, energy crop.

INTRODUCTION

Recent developments on bio-fuels bring rays of hope for greener future particularly in the context of fast declining non-renewable energy reserves and deteriorating global environment. Direct combustion of bio-fuels for cooking, heating and lighting is in practice since time immemorial and still is the major energy source for the people living in the rural areas of developing countries causing air pollution and health problems. Conversion of biomass into liquid fuel such as bio-ethanol, transesterification of bio-oils into bio-diesel and gasification of biomass to generate electricity are some of the promising options for efficient use of bio-fuels. Carruthers et al (1982) critically assessed the potential output of bio-fuel in the forms ranging from burning cereal straw or anaerobic digestion of animal wastes for producing methane to the large-scale planting of energy crops in UK and indicated future importance of these strategies and the impact of fuel production on agricultural systems of United Kingdom.

CONVENTIONAL BIOFUELS

Burning of biomass such as fuel wood, crop residues, cow dung cake, farm bi-products such rice husk, groundnut shell, coconut coir etc can be seen commonly on the country side of developing countries for different purposes ranging from cooking to parboiling of rice at farm level and even to get warmth during a cool winter evening. Biomass is the major source of energy in many developing countries including rural India and the demand for fuel wood affects both forest and agricultural systems. Analysis of Mahapatra and Mitchell (1999) pointed out that in many developing countries "socioeconomic factors influence bio-energy use, but scarcity of forests does not lower the demand for bio-fuels nor is it a driving force for farm level forestry". Hence, they suggested that energy need of rural areas of developing countries should be considered in forest policy and in their afforestation programme to meet the fuel demand of rural areas. The average quantity of bio-fuels consumed in Kenya is in the range of 0.8-2.7 kg capita-1day-1 in rural areas (Kituyi et al, 2001). Most of the households in Kenya are increasingly facing difficulties to access bio-fuels although it was reported in 1997 that the country is sufficient in fuel wood. Biomass burning is the major source of energy for about half the world's population mostly living in the rural areas of developing countries. The developing countries together harness 35% of their energy requirement from the biomass, the equivalent of 1088 Mt of oil (Groot, 1989). The combustion of crude biomass is the most common way of using the fuel. Another option for developing countries is the production of bio-gas for fuel and lighting and bio-gas slurry as manure by the process of anaerobic fermentation of vegetable and animal waste by bacteria. These biomass gases are of excellent source of energy but liquid energy is more convenient to use, store and distribute. As a result many countries like Brazil, USA, European Countries and Zimbabwe have initiated programmes for making bio-ethanol from sugars and starches. Some vegetable oils obtained from rapeseed, sunflowers, coconut, oil palm etc are promising alternatives for bio-diesel. Concern over the global climate change affected by the emission of CO_2 due to combustion of fossil fuel of which a large proportion is consumed by the transport sector, provides the much needed impetus for determined research and development of bio-energy, particularly bio-ethanol and bio-diesel for their use as fuel for motor vehicles either as pure or as blending (Groot, 1989).

BIO-FUELS TODAY

As the conventional forms of bio-fuels result environmental pollution, health problem and causes degradation for forest leading to ecological imbalance, the modern approach includes conversion of starchy and fatty tissues of plant or animal origin into simpler forms which can replace the mineral source of fuel to some extent.

BIO-ETHANOL

Ethanol produced from agri-resources (bio-ethanol) is widely used to replace gasoline partly in countries like Brazil and USA. In India 'gasohol' is introduced as a new age fuel that blends 5 per cent ethanol with petrol. Ethanol is extracted from molasses, a residue of sugarcane, which is available throughout the country. This is a significant step to diversify Indian agriculture and to widen the source of farm income in rural areas. Besides saving the country's scarce foreign exchange, ethanol has extensive benefits including a cleaner environment, reduced carbon di-oxide emissions and cleaner burning properties. As second generation bio-ethanol production, the lignocellulosic plant tissues are attempted to convert to ethanol through the saccharification and fermentation process. The plant and plant derived residues are converted into simple sugars by the use of enzymes. Then sugars are bio-converted to ethanol by fermentation (Lynd et al, 1991). The plant species commonly used for ethanol production are sugarcane, maize, sweet sorghum and sugarbeet. Everson (1978) reviewed various methods used in the manufacture of ethanol from whey and the economics of these processes. In early 1980's, there was mention of gasohol (10% anhydrous methanol or ethanol + 90% unleaded gasoline) as alternative fuel produced from cheese whey as feedstock for ethanol production (Lessley and Strand, 1980). The book entitled "Gasohol, a step to energy independence" edited by Lyons T P (1981) provides a clear understanding of the biology and the industrial technology of fuel alcohol production using whey, maize or cereal mash used as feedstock for alcohol production. The book also illustrates the possibility of an integrated system of distillery, maize production, cattle feeding and the production of methane from the slurry and its use as fuel. Adoptions of gasohol, organic farming and biomass conversion in an integrated manner are also proposed to consider in US Agriculture to make the food system less vulnerable to severe disruption and heavy dependence on fossil fuels (Castle and Woods, 1981). Brazil's bio-ethanol programme for motor vehicles has been successful and is the largest in the world. Sugarcane juice is fermented and distilled to produce bio-ethanol, which is used directly and or as lead-free gasohol (10-22% ethanol). The country has made a tremendous progress in bio-ethanol productivity of sugarcane with a record increase from 2700 to 3700 litres during the period of 1978 to 1986 in Brazil (Boddey, 1993). Some perennial grasses of North America such as switchgrass (*Panicum virgatum*) and coastal panic grass (*Panicum amarum*) have been identified as potential renewable energy crops for second generation bio-ethanol production (Madakadze et al, 1999; Christian et al, 2001).

BIO-DIESEL

Methyl and ethyl esters of rape, linseed and sunflower oils were prepared through transesterification of vegetable oils by using KOH and/or sodium alkoxides as catalysts and evaluated for their fuel properties. Apart from various fuel properties tested, the bio-diesels were found to be considerably less volatile

than the conventional diesel (Lang et al 2001). The seed oil of *Jatropha curcas*, a drought resistant tropical tree, has been identified as a potential source for the production of bio-diesel in Nicaragua (Foidl et al, 1996). In India, Jatropha and other non-edible tree borne oilseeds such as pongamia, neem, mahua etc. are being emphasized for bio-diesel production (GAIN, 2014).

SOLID BIO-FUELS

The use of biomass as solid fuels for the generation of electricity may be preferred to conversion of biomass to liquid fuels for transport which could be advantageous both ecologically as well as socio-economically (Hanegraaf et al, 1998). The biomass crops suitable for the generation of electricity are silage maize, hemp, poplar, willow and eucalyptus. Kumar et al (2002) estimated the monetary value of agricultural residues used as bio-fuels in India by proposing a simple demand side approach and indicated potential economic utilization of agriculture residues in boilers for heating and power generation.

RESEARCH AND DEVELOPMENT IN ENERGY CROPS

The annual crops and perennial trees which can be potentially exploited for the production of bio-fuels are commonly termed as energy crops. To gain a maximum benefit of energy crop, there is pursuance of research and development on identifying these crops, their adoption into the farming systems with perfection of cultural practices, monitoring ecological consequences and socio-economic feasibility. Further refinement of the conversion technology for the production of bio-fuels from biomass is needed to improve the efficiency of conversion that would subsequently bring down the price of bio-fuels. In India, vast waste and degraded land may be brought under energy plantation, which will not only produce biomass but also regenerate the soil productivity. Farm forestry may be adopted with coppice farming to generate biomass on sustained basis. Oleaginous crops like jatropha, castor, linseed, cottonseed and many other non-edible oilseeds can be explored for the production of bio-diesel in our country.

IDENTIFICATION OF POENTIAL BIO-ENERGY CROPS

The crops rich in starch and fatty acids and having quick growth that can be potentially used for bio-fuels have been identified in different countries based on technical feasibility, economic viability and agro-ecological adaptability. Some of the energy crops are already being grown for the purpose of bio-fuels. Brazil remains the pioneer country in adopting bio-fuel most widely and successfully where bio-ethanol production is mainly based on the fermentation/distillation of sugarcane juice and by-products (Boddey, 1995). In Europe, sugarbeet and wheat are the two most important alcohol-producing raw materials (Wouwer, 1986). In Germany, triticale was found to be most suitable for bio-ethanol production, while rye gave poor bio-ethanol production despite good grain yields (Rosenberger et al, 2000). Selection of bio-energy crop could be made based on the heating value of the biomass as Stencl and Sladky (2001) reported the highest heating value (17.2 MJ/kg) in case of stems of flax and that for Miscanthus and stems of Jerusalem artichoke was 15.5 MJ/kg. A better option of biomass production would be coppice farming with fast growing trees. In Belgium, short rotation coppice (SRC) with willow (*Salix* sp.) and poplar (*Populus* sp.) as a source of wood chips for energy production was compared with rape (*Brassica napus* var. *oleifera*) for bio-diesel and sugarbeet for bio-ethanol by Jossart et al (1994, 1995). SRC required less fertilizers and pesticides than rape or sugarbeet. Production of energy from SRC caused the lowest total CO_2 emission (0.3 t CO_2/ton oil equivalent) of the crops investigated. Use of rape oil methyl ester as bio-diesel for tractors was studied by Schrottmaier (1990).

Prosopis (mesquite) species has been identified for bio-fuel production on semi-arid lands of USA (Felker et al, 1981). The switchgrass (*Panicum virgatum*) has been chosen under Bio-energy Feedstock Development Program, USA as a model bio-energy species because of its high yields, better nutrient use efficiency, wider geographic distribution, positive environmental attributes regarding on soil quality and stability, its cover value for wildlife and relatively low requirement for energy, water and agrochemicals per unit of energy production. The efficiency of energy production for a perennial grass system (such as switchgrass) can exceed that for an energy intensive annual row crop (such as maize) by as much as 15 times and estimated carbon sequestration rates may exceed those of annual crops by as much as 20-30 times (Mclaughlin and Walsh, 1998).

In the Asian-Pacific region, there is tremendous increase in production of cassava/tapioca. Singh (1986) emphasised diversified utilization of cassava roots including gasohol production, but pointed out the technological limitations for commercial production except for starch. However, Aggarwal et al (2001) identified tapioca starch as cheaper substrate than molasses for ethanol production. They used a commercial preparation of alpha-amylase, Biotempase, and crude glucoamylase produced from Aspergillus sp. NA21 to hydrolyse tapioca powder and established an economical process of liquefaction and saccharification of tapioca starch. The sago palm (*Metroxylon sagu*) is found in the equatorial swamp forests of Southeast Asia. Earlier sago starch was extensively used as a staple food but presently it has been replaced by cereals. In search of bio-fuel as alternative renewable energy source, the sago palm has been identified as potential energy crop for the production of gasohol through exploitation of its natural habitat as well as cultivating under agro-forestry system (Stanton and Flach, 1980). With regard to agricultural materials as energy sources and heat production, straw, reeds and Miscanthus were most attractive but not ideal for bio-ethanol and esterified bio-diesel production (Onna, 1991).

POTENTIAL BENEFITS OF ENERGY CROP/BIOFUELS

The potential benefits of bio-fuels can be of economical, environmental and ecological. A nation like India dependent on import of mineral oils can save its foreign exchequer by adoption of bio-fuel technology into practice at wider scale with policy intervention. The ethanol, made from molasses, a bi-product of sugar industry, can be added to petrol to overcome the problem of increasing import of petroleum products and to decrease environmental pollution while increasing the profit margins of shrinking sugar industry (Dahiya, 1988; Sharma and Goel, 1997). Arora et al (1982) viewed the diversity of biomass feedstock and their relatively even distribution as the factors which can be exploited for rural welfare by increasing per capita consumption of bio-fuels in rural areas. Onna (1991) emphasized replacing fossil fuels with bio-energy (e.g. bio-ethanol and bio-diesel) as an option to lower down emission of CO_2 gas into atmosphere particularly by motor vehicles. Bio-ethanol is regarded for its possible use as lead-free fuel (Bublot and Tychon, 1990). With the introduction of bio-ethanol as motor fuel, lead pollution in Sao Paulo and other cities of Brazil fell by 75% in ten years during nineteen eighties (Boddey, 1993). Adoption of plantation of bio-energy crops like jatropha, switchgrass etc on wasteland and degraded land will not only benefit the economy and livelihood of the rural people but also enrich the ecological diversity and stability of the area.

LIMITATIONS OF ENERGY CROP/BIOFUELS

Economic non-viability is the major constraint in adoption of bio-fuel technology at the wider perspective in many countries. The policy of subsidization of petroleum fuel lowering its market price makes bio-fuel less competitive in the market. Availability of sufficient feedstock for bio-ethanol/bio-diesel round the year is also limited by the seasonal nature of production of energy crops. Technology is also limiting for the direct production of bio-ethanol from cellulosic and lingo-cellulosic feedstock which are available in plenty at farm levels. The use of bio-fuels at farms of USA is constrained by high initial investment costs, low or negative energy efficiency, and limited economic feasibility (Webb and Duncan, 1979). With increasing oil prices and stagnation of grain prices, bio-ethanol would be economically competitive potential alternative fuel (Austin, 1979). Gordon and Gorden (1982) opined that gasohol is already cost-efficient in some developing countries and will become more economical as fuel prices rise and as more grain for ethanol becomes available but pointed out the availability of a feedstock and the extensive land required to grow sufficient quantities as limiting factors.

Some authors also anticipated the destabilization of market price for food crops such as maize, wheat etc as more of this food grains are diverted for the purpose of bio-ethanol production. In USA, gasohol, (a mixture of 90% unleaded gasoline and 10% anhydrous alcohol) gained commercially viability as a motor fuel mainly because of subsidies and high prices for petroleum. It was predicted that use of maize as a feed-stock for alcohol production would lead to higher maize production and prices and might lower soybean production and prices and high levels of use of maize in alcohol production could substantially reduce maize stocks, and thereby could destabilize maize, livestock, and food prices (Meekhof et al, 1980).

The entire system of bio-fuel production to be energy efficient, the ratio of energy output to total energy input in every form including tillage operations, fertilizers etc should be more that one. Batchelor et al (1994) while studying economic viability of bio-ethanol production from wheat grain in UK, pointed out that the non-renewable energy input should be less than the total energy output in the production system for bio-fuel production system to be viable and concluded that the development of bio-ethanol as a motor fuel will be possible if the energy balance is improved and/or the price of oil increases considerably. Garstang (1993) also indicated uncertainty for crops grown for biomass, bio-oils and bio-ethanol both in terms of crop performance and financial support in long term.

CONCLUSION

At present some countries particularly Brazil, USA and European countries adopted bio-fuels in the forms of bio-ethanol and bio-diesel to replace motor fuel to some extent. Its larger use is desirable in view of its benefit from renewability by growing bio-energy crops and arresting the CO_2 accumulation in the atmosphere which is a great concern in relation to Global Warming and Climate Change. Technological breakthroughs for economical conversion of cellulosic, hemi-cellulosic and ligno-cellulosic biomass into bio-ethanol and policy orientation making biofuels market competitive are the need of the hour for wider adoption of biofuels to ensure greener future development.

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